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ANVIS Compatibility With HGU-56/P Helmet

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Physical compatibility assessments of the Aviator Night Vision Imaging Systems (ANVIS) were completed on subjects wearing the HGU-56/P. Data were obtained from 172 subjects participating in a helmet fitting study. Subjects were fitted with the HGU-56/P developer-recommended helmet size based on head length and up to two additional sizes (smaller and larger). On several subjects, compatibility assessments included the M-43A1, type 2, protective mask.. Additional measurements of minimum ANVIS eye clearance using rigid head forms were taken to compare with similar data obtained from the subjects. Our results indicate (1) most subjects achieved acceptable ANVIS mechanical compatability and acceptable eye relief while wearing the HGU-56/P, (2) placement of the ANVIS mount higher on the visor cover will increase compatibility, (3) fitting one size larger than the developer-helmet size probably will be required to achieve acceptable and comfortable fit while wearing the protective mask.

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EXECUTIVE SUMMARY

ANVIS mechanical positioning data were taken from 172 of the 242 subjects used in the HGU-56/P helmet fitting study. This study was conducted at Ft. Rucker, Dec 1992. Subjects were fitted with the Gentex recommended helmet size based on head length, and up to two alternate sizes of the HGU-56/P helmet. On a few subjects, a general fit and ANVIS vertical height alignment were assessed with the M-43A1, type two, protective mask. Relative measurements of head/helmet tilt were obtained to determine variability between subjects of a perceived level head position. In the laboratory, the minimum ANVIS eye clearance measurements were taken with USAARL aviator rigid headforms for correlation analysis with the subject data obtained in this study.

The results showed the following:

(A) Only a small percent of the helmet wearers had excessive and unacceptable eye relief with ANVIS. The larger the helmet for the "best fit" criteria and for a given head size, the greater the measured minimum eye clearance with ANVIS.

(B) The data also suggest that placement of the ANVIS mount higher on the visor cover would reduce the unacceptable percentage from insufficient upward vertical adjustment range.

(C) The small sample size (18) and method of assessing helmet compatibility with the M-43 protective mask were insufficient for conclusive significance, but the helmet fitters' impressions were that a helmet size larger than the one recommended by the manufacturer's guide would be required to provide an acceptable and comfortable fit with the mask. Using primarily the one size larger helmets than the manufacturer's recommended size, the masks showed ANVIS insufficient upward vertical adjustment range for 29% of the subjects with acceptable helmet and mask fits. The eye clearance for ANVIS was not evaluated with the M-43 protective mask in this study.

(D) The relative tilt angle of the helmet when the subjects perceived their heads in a level position showed considerable variability (range of 19 degrees, 4.9 degrees for one standard deviation). The relative helmet tilt variability was much smaller, as expected, when the subjects centered a specified object in the ANVIS field of view (range of 5 degrees, 1.7 degrees for one standard deviation).

In the Laboratory study, fore-aft and relative helmet/ANVIS tilt angles were measured using different sized helmets on five different sized rigid headforms. These measurements will provide a database for comparative analysis with ANVIS of eye clearance and tilt angles for future helmet modifications or designs.

Note to reader- Preliminary data from this study were supplied to the program manager for the HGU-56/P helmet in January 1993. Since that time, the ANVIS mount on the helmet has been moved upward approximately 5 millimeter; the visor cover and ANVIS mount were modified to expose more of the low battery warning light; and the helmet suspension system was changed by lowering the nape strap attachment point and moving the chin strap attachment to the ear cups.

The modified suspension system for the HGU-56/P helmet was reevaluated for ANVIS compatibility. Using the medium USAARL aviator rigid headform, minimum ANVIS eye clearance measurements were repeated between the suspension system used in the December 1992 helmet fitting study and the modified suspension system. There was no measurable difference in the ANVIS eye clearance between the two suspension systems since the helmet shells, foam liners, and TPLs were the same thickness for both helmets.

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Introduction

The HUG-56/P helmet is intended as the next generation Army aviator helmet and would replace the current SPH-4 and SPH-4B helmets. As part of the assessment of the HGU-56/P helmet fitting study, the compatibility of the Aviator Night Vision Imaging System (ANVIS) and helmet were evaluated by using as subjects the intended wearers of the helmets (Bruckart et al., 1993). In a previous USAARL study of eye relief and in-flight field-of-view (FOV) (Kotulak, 1992), the compatibility of the standard ANVIS with the SPH-4 helmet was determined to be poor. Data showed that the majority of aviators had excessive eye relief when ANVIS was adjusted to the closest position to the eyes. This excessive eye relief resulted in reduced fields-of-view through ANVIS.

USAARL also evaluated the compatibility of ANVIS with the dual visor SPH-4B helmet (McLean and Frezell, 1991). The study compared the available ANVIS mechanical adjustment ranges with both the SPH-4 and SPH-4B helmets. The study was conducted in two parts. One method consisted of a subjective questionnaire from night vision goggle (NVG) aviators and the other method used USAARL aviator rigid headforms for comparison of the two helmet types. No measurable differences were found with the minimum ANVIS eye relief between the SPH-4 and SPH-4B helmets, but a difference of approximately 6 degrees was found between the middle ANVIS tilt angle values of the two type helmets. Corrective actions recommended for those SPH-4B helmet wearers with insufficient tilt and fore-aft adjustments with ANVIS were to modify the thermo plastic liners (TPL) by heating and/or cutting the liners by trained ALSE personnel.

In the present study, ANVIS compatibility was evaluated with the HGU-56/P helmet for eye clearance and the vertical adjustment position on the ANVIS mount using aircrew members and USAARL rigid headforms.

Methods

Method 1- ANVIS mechanical adjustment positions on Army flight personnel

Subjects

There were 242 subjects (student pilots, instructor pilots, crew members, and members of an operational aviation unit) used for the helmet fitting study. Of those who achieved an acceptable helmet fit with the HGU-56/P, 172 subjects were evaluated for ANVIS compatibility. An average of 2.1 evaluations per subject was conducted with different sized helmets for ANVIS

compatibility. Subsets of this group were used for the M-43A1, type 2, protective mask and helmet/ANVIS assessment and the helmet/ANVIS relative tilt angle evaluation. The participants ranged in age from 18 to 52, with a mean age of 28. Ten of the subjects were females.

Procedures

ANVIS vertical height, eye relief, and FOV.

The subjects were fitted in their recommended HGU-56P helmet size in accordance with Gentex fitting method and up to two alternate sizes. The helmet fitter tried to use the next helmet size larger and smaller for the two additional fittings. For most of these subjects, compatibility with the AN/PVS-6 ANVIS was evaluated only if the helmet fit was scored as acceptable by the helmet fitter and the helmet wearer.

The left tube of the ANVIS was occluded with an opaque lens cover, and the right tube had a lighter attenuating translucent lens cover so that the ANVIS could be turned on in room illumination without damaging the image intensifier tubes. A complete 40 degree green circle without any vignetting (edge shading) in the right tube would be seen by the observer, if he/she was aligned properly with the ANVIS eyepiece optical axes, and the eye entrance pupil was within a certain eye clearance distance.

The subjects were asked if they were qualified and familiar with the adjustments on the ANVIS. If not, they were shown the location of the vertical and interpupillary (IPD) adjustment knobs, and instructed on how to align the green circular image seen by the right eye using the sighting method (Figure 1). Additional instructions were given to illustrate the difference between a full field-of-view and an obstructed field-of-view.

The subjects were directed not to adjust the tilt or eyepiece focus. The ANVIS tilt lever was set in the middle position and the eyepiece diopter values were fixed at -0.50 diopters. The fore-aft adjustment was positioned in the most rearward location (closest to the eyes). The subjects were not permitted to alter the position of the ANVIS fore-aft unless the eyepieces touched their eyelashes.

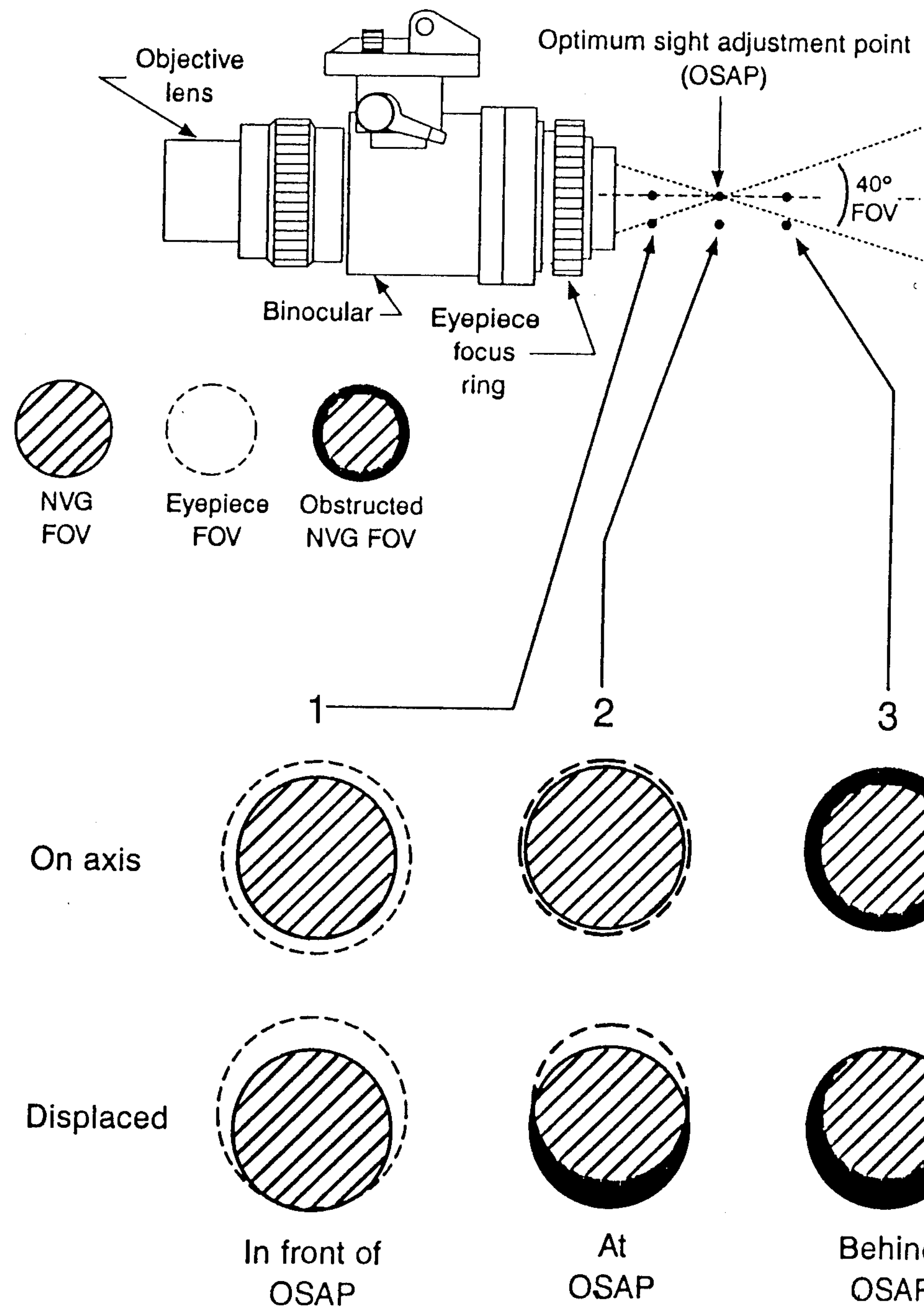

Figure 1. Full and obstructed ANVIS field-of-view.

If the subject reported any shading of the 40 degree field-of-view of the displayed green circle after completion of the adjustments, the researcher determined whether the shading was from excessive fore-aft, inadequate vertical adjustment range, or interpupillary distance (IPD) misalignment by the subject. If the subject misadjusted the visual and optical alignment, he/she was coached to move the ANVIS tube in the direction of the edge shading to obtain crisp edges of the green circle. If the shading of the image could not be resolved using all of the available range of ANVIS adjustments, then the ANVIS compatibility was labelled unacceptable.

Once the FOV was centered, the subject was instructed to sit at an adjustable height table that contained a chin rest and a three-axes translating telescope which had a cross hair. The telescope was 7 power and fitted with a 175 mm focal length lens for near focus. The field-of-view through the telescope was approximately 18 mm (6°) at 175 mm viewing distance (Figure 2). The height of the table was adjusted until the goggle tubes were level. Changing the height of the table changed the pitch angle of the subject's head and goggles in order to position the tubes horizontally. The subject's head was rotated (yaw) until the ends of the right and left eyepieces were aligned perpendicular with the telescope. The researcher measured the eye clearance or distance between the subject's corneal apex and the rearmost part of the ANVIS eyepiece for the right eye, reading from a millimeter scale on the telescope mount.

If the eye relief was unobtainable due to the position of the subject's eye and the extended position of the visor cover on the side of the helmet, the eye clearance was measured using a parallax compensating millimeter ruler. At the same time, a research assistant would ensure that the tilt adjustment was in middle location and the fore-aft was all the way back. If the fore-aft was not at the most rearward position because of potential contact of the eyepieces with the eyelashes, the displaced position was measured and recorded so that the minimum eye relief measurement could be calculated. The assistant also measured and recorded the ANVIS vertical height adjustment position on the helmet visor.

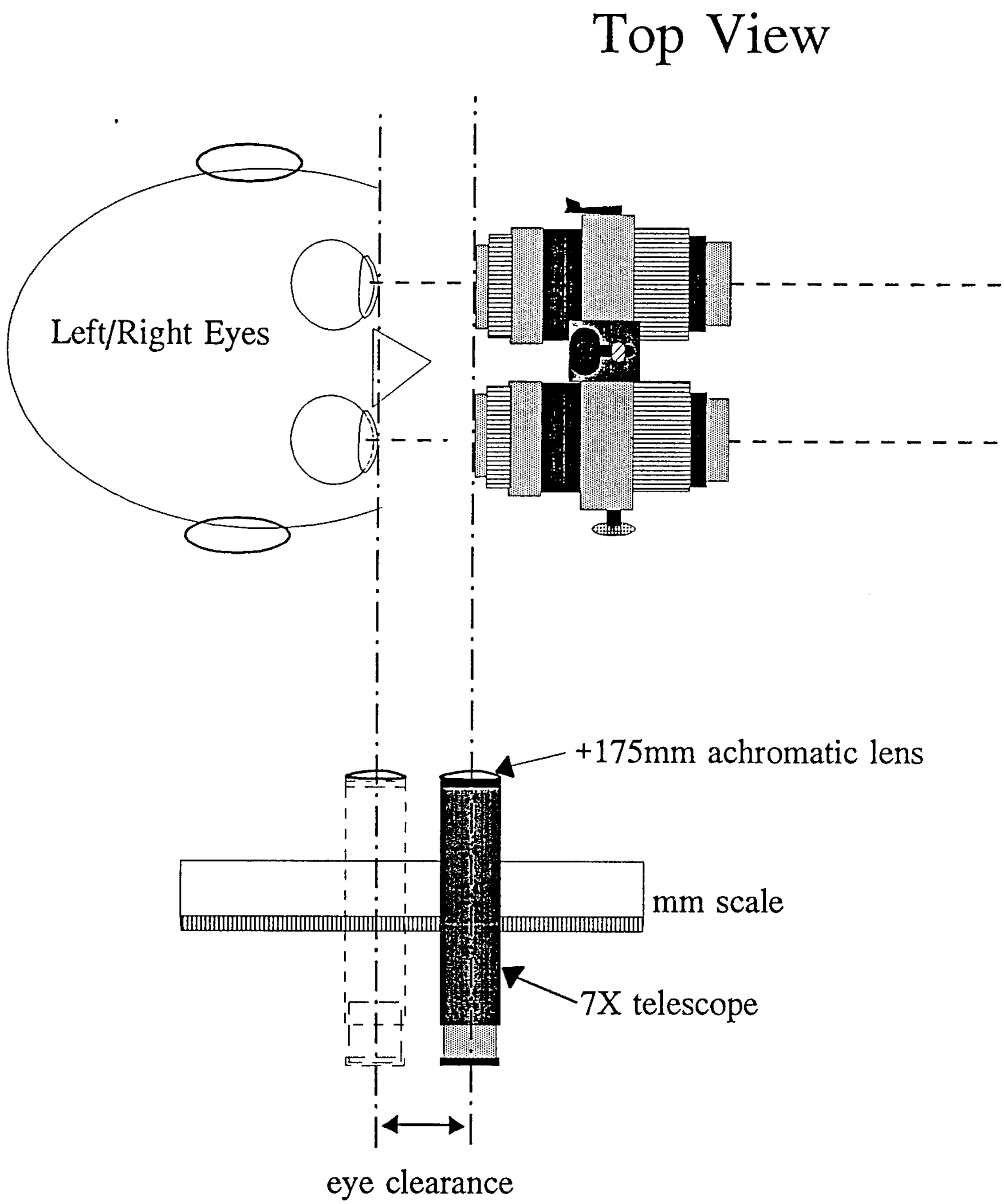

Figure 2. Eye clearance measured with telescope.

M-43 protective mask and ANVIS compatibility

Eighteen of the subjects were fitted with an M-43 mask. The helmet size that was judged most comfortable and best fitting generally was selected to be evaluated with the mask. The ANVIS was attached to the helmet and the subject adjusted the vertical and IPD knobs to obtain optical alignment. The only change to the ANVIS adjustment procedure as explained above was that the fore-aft initially was placed in the most forward position from the eyes to allow clearance between the lenses of the mask and the ANVIS eyepieces. The subjects then moved the ANVIS as close to the mask as possible.

An acceptable score was recorded for the mask only if one of the investigators determined that the ANVIS could be positioned in front of the lenses of the mask within the available ANVIS vertical adjustment range on the helmet mount in order to center the field-of-view. The eye relief required for clearance between the ANVIS eyepieces and the mask lenses, IPD staples, corrective lens outserts, eye pads, or the nasal cup most likely would reduce the field-of-view for most of the M-43 protective mask wearers with the standard ANVIS, but this was not measured in this study. See Appendix B for data from a previous ANVIS and M-43 mask compatibility study.

Helmet/ANVIS relative tilt angles

Thirty-one subjects were selected randomly to follow the ANVIS eye clearance and vertical height adjustment measurements with helmet tilt measurements. A gravity type inclinometer, marked in 1/2 degree increments, was placed on the top of the helmet shell with one contact point on the top of the visor cover next to the ANVIS' dual battery electrical connector (Figure 3). This measured tilt angle is only a relative value and was used primarily to determine the range and variability of the user's perceived level head position. The actual ANVIS tilt angle was calculated from measurements in the laboratory on the rigid headforms (See method 2 in this report for determination of the actual ANVIS tilt angle to the measured relative helmet tilt angle.) The opaque lens cover and light attenuating translucent filter were attached to the objective lenses as before.

Instructions to the subjects who were wearing a test helmet with attached ANVIS and optional counterweight were to close their eyes, move their heads up and down approximately 45 degrees above and below the horizon twice. While keeping their eyes closed, they were asked to center their head in a level position as if they were looking out the front of their aircraft. A tilt measurement then was obtained. The subjects were asked to open their eyes and center the ANVIS field-of-view as if they were looking out of the aircraft. A 0.3 kilogram counterweight was used if they normally used a counterweight with ANVIS.

Figure 3. Helmet relative tilt angle measurements.

Helmet tilt measurements were taken on 12 additional subjects, who were instructed to center a small light in the ANVIS' field-of-view after the tilt measurement was taken with the subject's eyes closed. For this particular procedure, special daylight training filters were used to obtain an image of a small light through the ANVIS. All subjects were required to use the counterweight. The small light was across the room (>15 feet) at approximately the eye level height of the seated subject.

Significant comments from the subjects and observations by the members of the research team also were recorded. Some of the helmet fitters recorded which helmet size gave the best fit. Of the 151 records indicating the helmet size for best fit, 93 had data of the ANVIS vertical position and eye clearance distances.

Results

ANVIS compatibility with HGU-56/P helmet

Table 1 shows the summary results of the percent of subjects with acceptable helmet fits that had unacceptable ANVIS compatibility due to either inadequate vertical adjustment range or excessive eye clearance. The unacceptable percentages are given for the subjects wearing the Gentex recommended size, one size larger, and one size smaller helmet. The unacceptable ANVIS compatibility percentages also are broken down by vertical and eye clearance criteria. As the helmet size increased relative to the head size, the percent unacceptable ANVIS compatibility cases increased for both excessive eye relief and inadequate vertical adjustment range. The percent of acceptable ANVIS compatibility also is shown.

Table 1.
Summary of ANVIS compatibility with HGU-56/P helmet.

1 helmet size down on same size head	Gentex recommended helmet size	One helmet size up on same size head
Total N=51 Unacceptable: Eye clearance=0 Vertical=2 Total=2 % of total= 3.9 Acceptable: 96.1%	Total N=142 Unacceptable: Eye clearance=5 Vertical=8 Total=13 % of total = 9.2 Acceptable: 90.8%	Total N=140 Unacceptable: Eye clearance=10 Vertical=20 Total=30 % of total = 21.4 Acceptable: 79.6%

A breakdown of the unacceptable ANVIS compatibility cases by each of the six helmet sizes is located in Appendix A.

On 151 of the data forms, the helmet fitters had indicated the best fitting size helmet for that subject. On 93 of these forms, ANVIS compatibility data were taken for the vertical position and eye clearance distance. The size of the helmet selected as the best fitting relative to the recommended helmet size for the subject's head length is summarized below:

4% were smaller than the Gentex recommended size
39% were the recommended size
55% were one size larger than recommended size
2% were two sizes larger than recommended size

Vertical height adjustment

All of the unacceptable vertical adjustment range cases were from the ANVIS mount being too low on the helmet shell. That is, the subjects could not raise the ANVIS high enough to align with the optical axes of the eyepieces with the tilt lever fixed in the middle position.

Figures 4-6 show the cumulative distributions of the distances for the aligned ANVIS position measured from the upper limit of the mechanical adjustment range. The 5, 50, and 95 sampled percentiles are indicated in each figure for the recommended helmet size (Figure 4), one size larger (Figure 5), and one size smaller (Figure 6). Negative abscissa values represent those individuals who could not properly align their ANVIS because of an inadequate upward adjustment range. These individuals arbitrarily were assigned a value of -1.5 mm. The ANVIS total vertical adjustment range is 17 mm with a middle value of 8.5 mm for the upper limit.

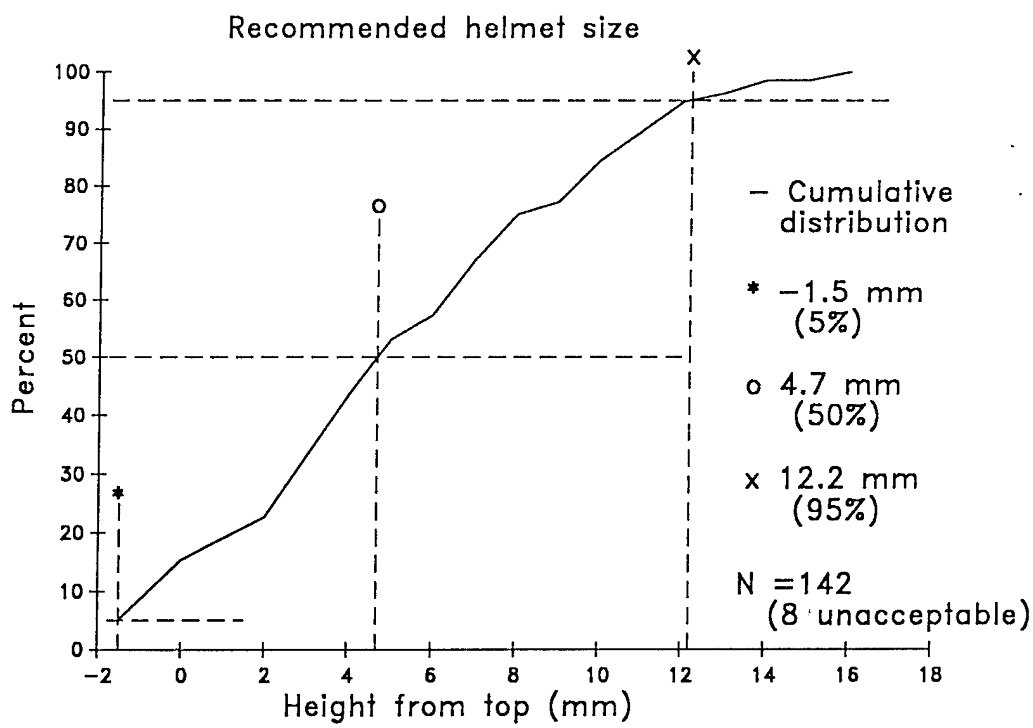

Figure 4. ANVIS vertical height adjustment on HGU-56/P, recommended size.

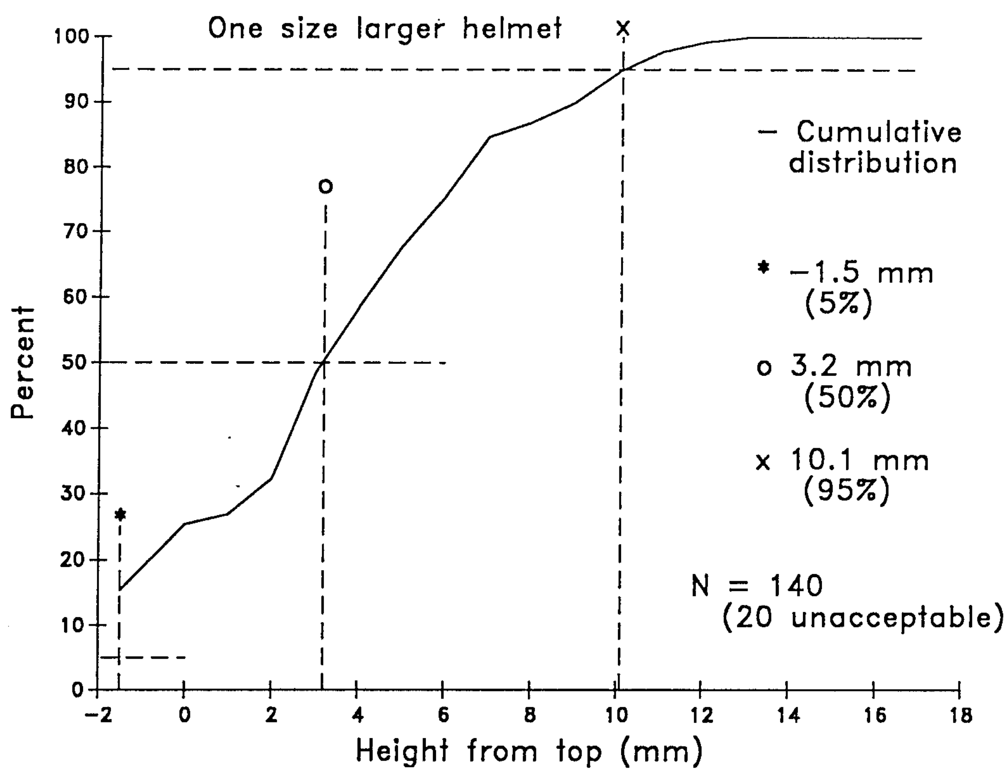

Figure 5. ANVIS vertical height adjustment, one size larger helmet than recommended.

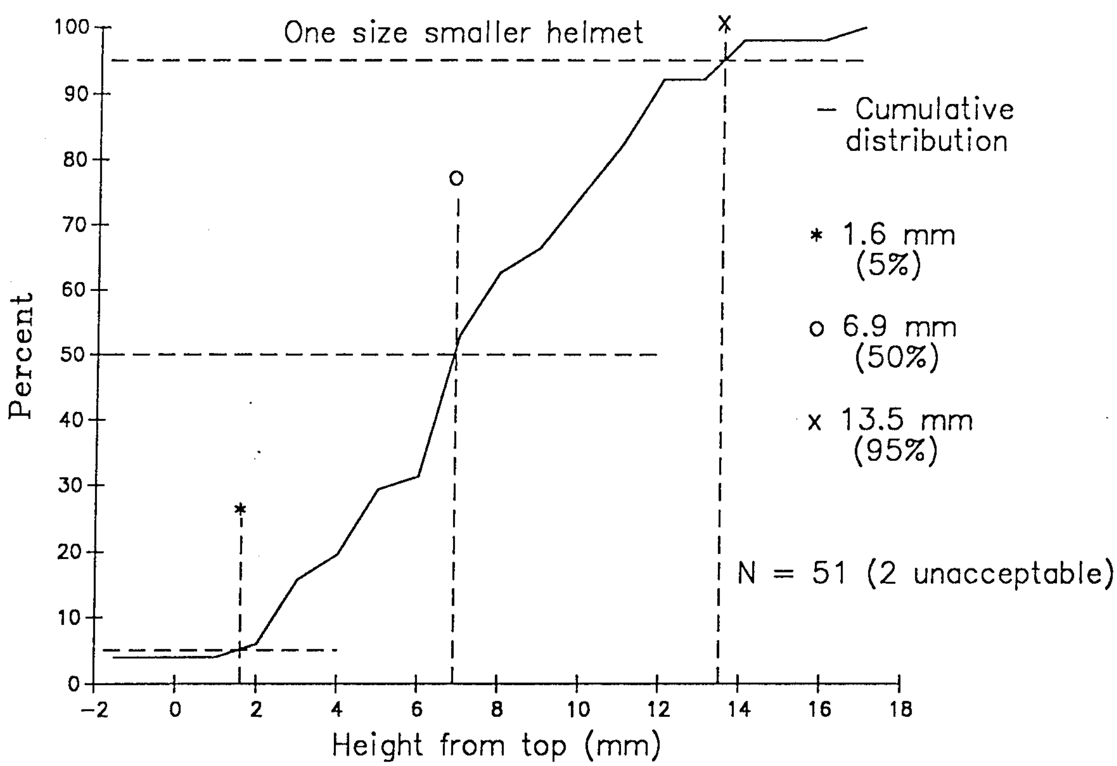

Figure 6. ANVIS vertical height adjustment, one size smaller helmet than recommended.

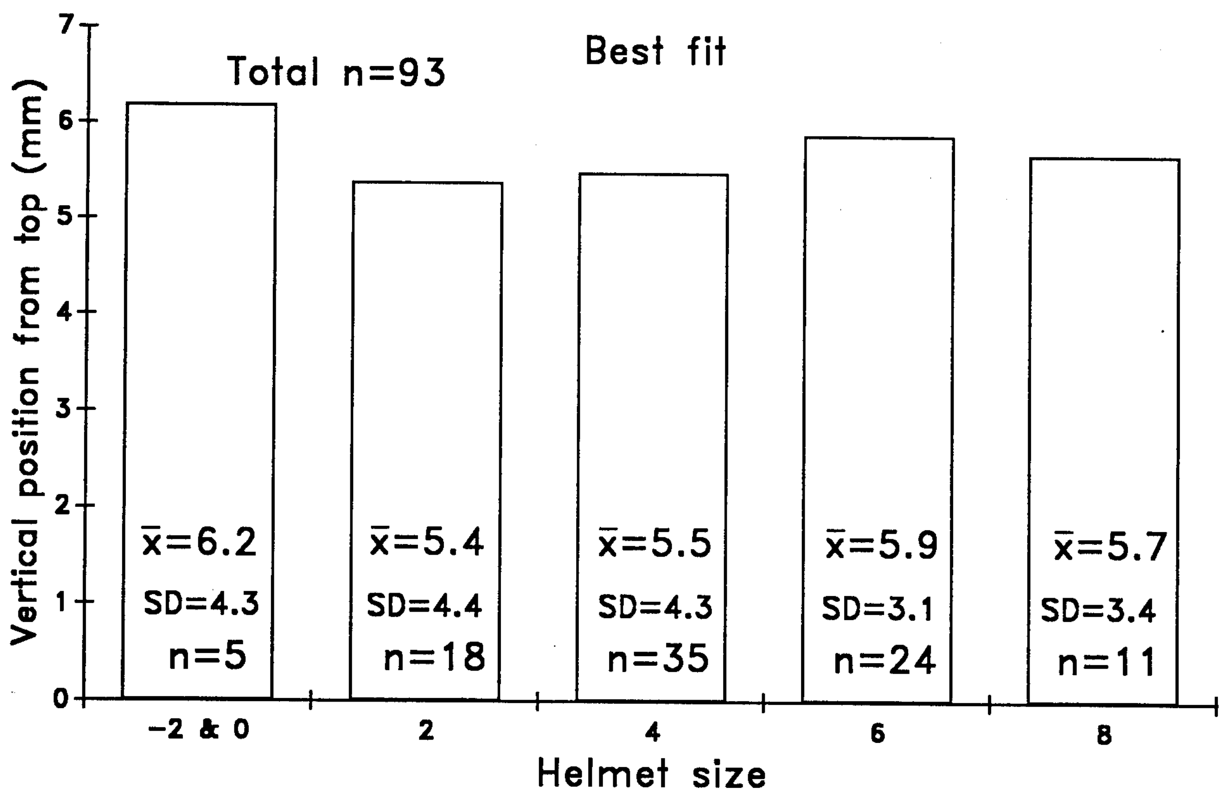

Figure 7. ANVIS vertical adjustment, "best fitting" helmet size.

Figure 7 shows the means for the ANVIS vertical position for each size helmet when judged to be the best fit. The means ($\bar{x}$), standard deviations (SD), and sample size (N) are located in the bar corresponding to each size helmet.

Minimum eye clearance

Figures 8-10 show the data for the minimum ANVIS eye clearance for the HGU-56/P helmets using the recommended size, one size larger, and one size smaller. These graphs include all the subjects with acceptable ANVIS vertical position alignment and the subjects with unacceptable eye clearance resulting in reduced fields-of-view. Note that as the helmet size increased from the one size smaller to the one size larger than the recommended size, the ANVIS eye clearance values also increased, producing more excessive eye clearance distances.

Figure 11 shows the mean eye clearance for each helmet size using the helmet size labelled as the "best fit." The means ($\bar{x}$), standard deviations (SD) and number of subjects (N) for each helmet size are located within the bars. The data indicate that as the size of the helmet increases for the helmet labelled as "best fitting," the minimum ANVIS eye clearance also increases.

The eye clearance data by helmet size in tabular form are located in Appendix A.

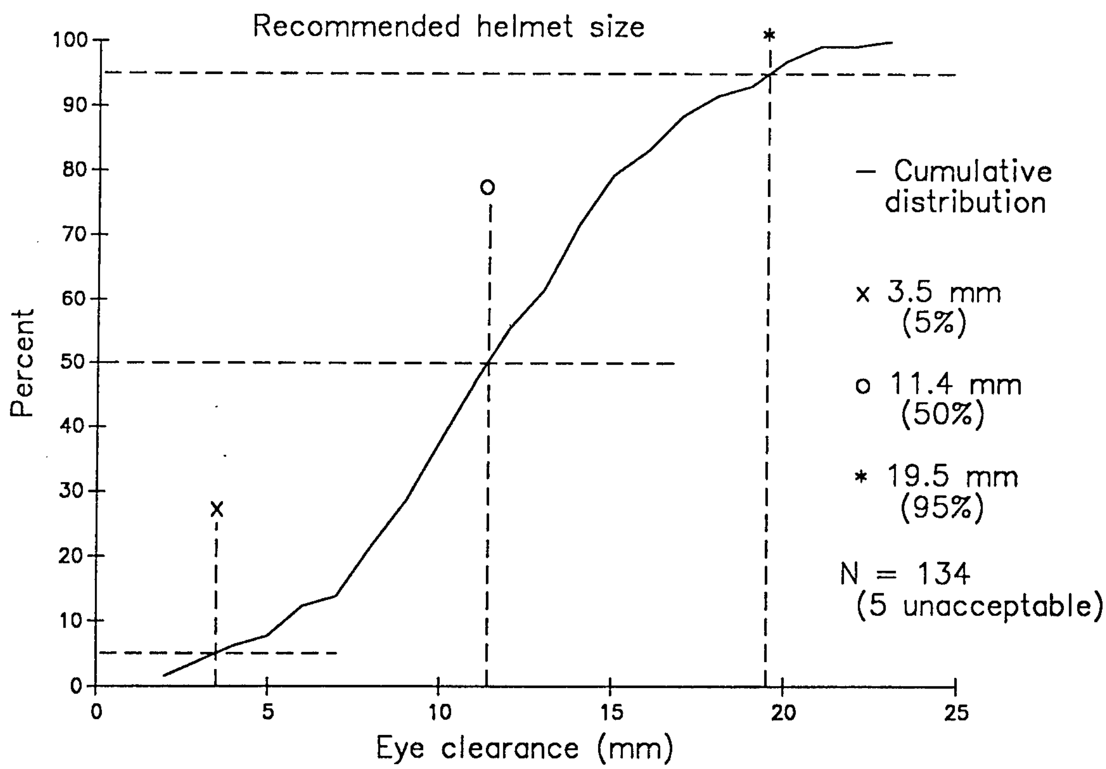

Figure 8. ANVIS minimum eye clearance on HGU-56/P, recommend helmet size.

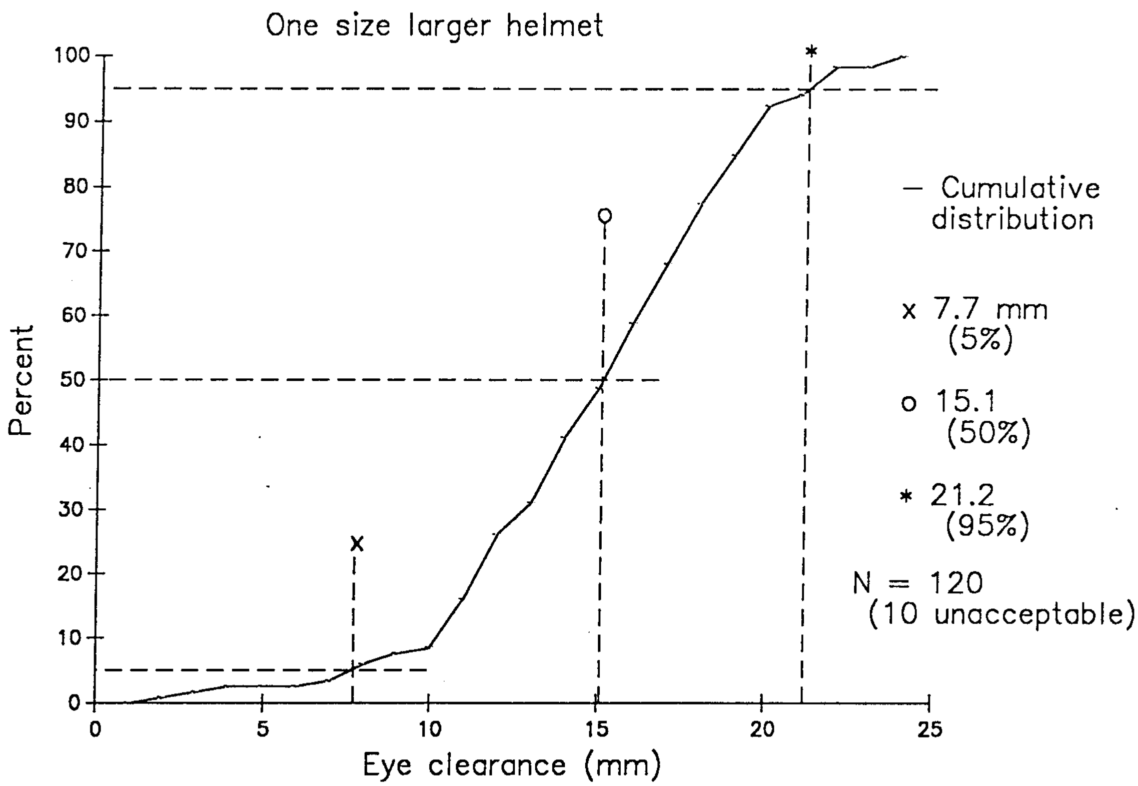

Figure 9. ANVIS minimum eye clearance, one size larger helmet than recommended.

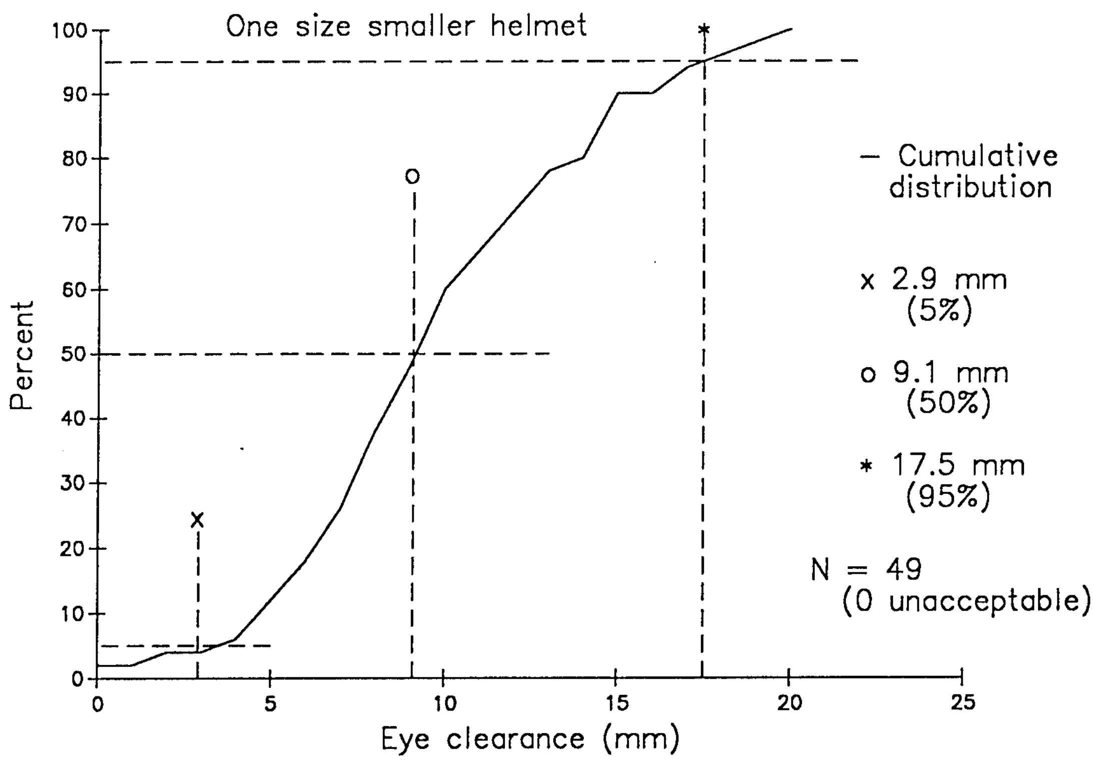

Figure 10. ANVIS minimum eye clearance, one size smaller helmet than recommended.

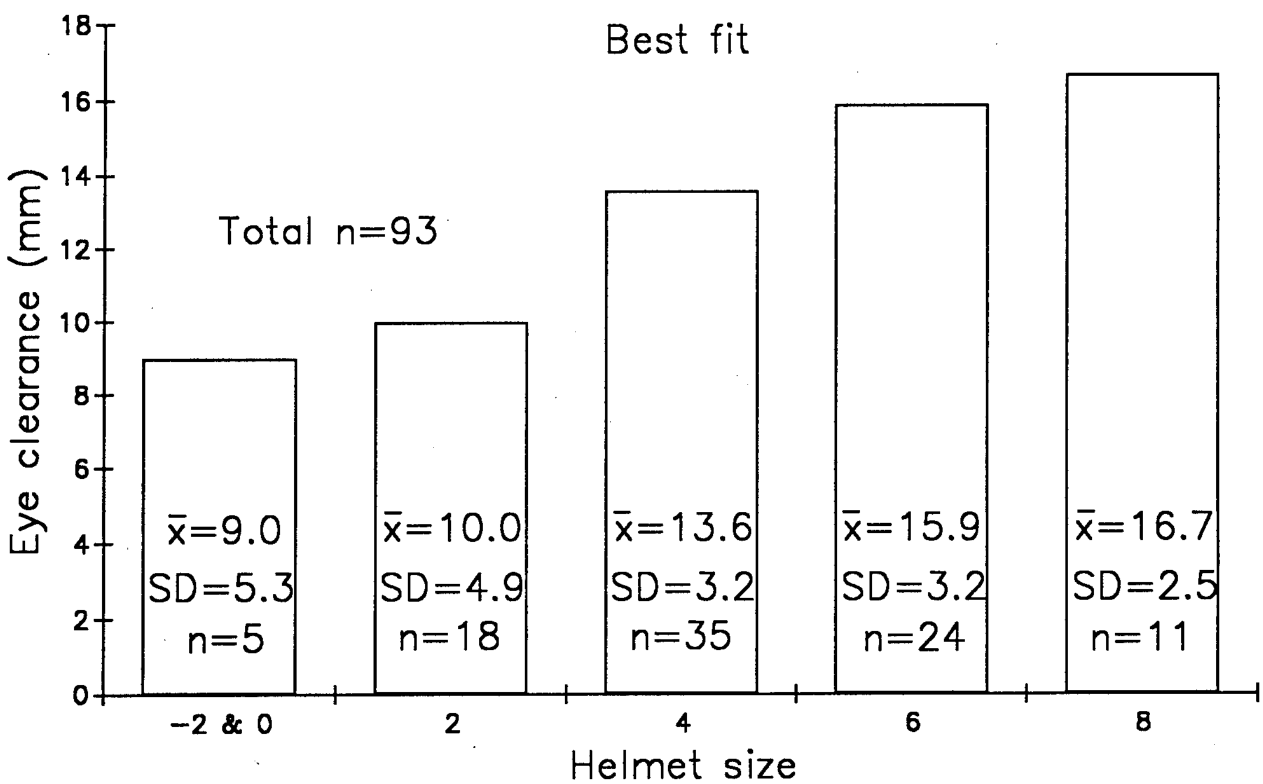

Figure 11. ANVIS minimum eye clearance, "best fitting" helmet size.

Compatibility with M-43A1, type 2 protective mask

Although a larger sample size was planned for evaluating the compatibility of the M-43 A1, type 2, protective mask and helmet, only 18 subjects had protective mask data recorded. Of those fitted with the M-43 protective mask, 12 (67 percent) of these subjects were wearing the next larger sized helmet than the size recommended by the Gentex fitting guide. Fourteen of the 18 subjects (78 percent) rated the helmet and protective mask as an acceptable fit. Ten of these 14 (71 percent) who had acceptable helmet fit with the masks or 10 of the 18 total fitted with the mask, (56 percent), had satisfactory helmet/mask fit and vertical ANVIS optical axes alignment.

Satisfactory ANVIS optical alignment with the M-43 mask does not necessarily mean acceptable ANVIS compatibility. The design of the lenses in the M-43 mask allow a much closer eye relief to optical devices such as NVGs, optical relay tubes (ORT) in the Cobra, telescopes, binoculars, etc., than any other fielded protective mask, but the minimum eye clearance to the ANVIS eyepieces may be greater than 20 mm for many individuals, especially those requiring frontsert optical corrections. The excessive eye clearance beyond approximately 20 mm reduces the field-of-view through ANVIS, and an acceptable minimum field-of-view value for flight with ANVIS has not been determined.

Field-of-view data through ANVIS using the M-43 masks with and without prototype frontserts for optical corrections were obtained in a previous USAARL study with the 15 subjects wearing an SPH-4 helmet. Since the minimum eye clearance with ANVIS mounted on the SPH-4 helmet is greater than measured with the HGU-56/P, then the fields-of-view through ANVIS on the HGU-56/P helmet with the M-43 mask should be equal to or greater than those measured with the SPH-4 helmet. The data on the eye clearances and ANVIS FOV from an unpublished USAARL study of the M-43A1, type 2 masks are located in Appendix B.

Relative helmet tilt measurements

For 31 subjects, the <u>relative</u> helmet tilt angles were measured in order to calculate actual ANVIS tilt angles from laboratory data. Table 2 summarizes these data by mean, standard deviation, and range. The primary importance of the data is the variability and the range of values.

Table 2.
ANVIS tilt angle data for perceived level head.

Condition	Mean tilt angle	1 SD*	Minimum - maximum
Eyes closed	4.9 degrees down	4.9	-5 to 14 degrees
Eyes opened	4.2 degrees down	3.8	-5 to 10 degrees

* 1 SD = one standard deviation

For the second set of 12 subjects, the same instructions for the eyes closed condition were given. However, with the eyes opened, the subjects were required to center a small light in the ANVIS field-of-view. Also, all subjects were required to use the counterweight, which was optional for the first set. The centered field-of-view condition would represent an approximate goggle level position with the tilt level in the middle position. Table 3 shows the resulting calculated ANVIS tilt data for the mean, standard deviation, and range. Note that the standard deviation (1 SD) and range for the perceived level head positions with the eyes closed were much greater than the centered field-of-view.

Table 3.
ANVIS tilt angle data for perceived level head and centered FOV (second group).

Condition	Mean tilt angle	1 SD	Minimum-maximum
Eyes closed	3.2 degrees down	4.6	-7 to 7 degrees
Centered FOV	1.4 degrees down	1.7	-2 to 3 degrees

Additional observations and comments

Several subjects commented that the side supports for the visor rails and the central extended part of the visor cover where the ANVIS mount attached blocked their peripheral vision or were a distraction compared to the SPH-4 helmet.

On the last day of the study, several batteries in the ANVIS dual battery packs activated the red LED low battery warning light on the ANVIS mount. When the subjects were told to ignore the light and switch batteries, they responded that the warning light was not visible when the helmet was donned. Several of the researchers verified that the visor cover extended a few millimeters below the base of the ANVIS mount, blocking the

user's line of sight to the red LED. Even after being dark adapted, when the ANVIS was on, the observers could not see the activated red LED because of the obstruction by the visor cover. The program manager was contacted to correct this deficiency.

Discussion

Our measurements indicate that the ANVIS mount should be moved upward on the prototype HGU-56/P visor cover or the visor cover moved approximately 3 millimeters to reduce the unacceptable ANVIS compatibility percentage due to insufficient vertical adjustment range. Also, the visor cover between the eyes and the ANVIS helmet mount should be redesigned to prevent blocking the low battery light LED indicator.

The ANVIS eye clearance data for the HGU-56/P helmet are excellent with more than 95 percent of the subjects having a minimum value of less than 20 millimeters when fitted with the recommended helmet size. With a size larger than the recommended helmet size, the minimum eye clearance value for the 95 percentile value was less than 22 millimeters. The minimum amount of measured eye clearance that was reported to reduce the field-of-view by a subject was 19 millimeters, and the maximum eye clearance reported for obtaining a full field-of-view was 23 millimeters. This range for the minimum eye clearance needed to obtain a full field-of-view with ANVIS is not unexpected for the size of the sample, and especially for the criteria used by the subjects in determining whether the edges of the 40 degree field-of-view were sharp.

As the helmet sizes increased with both the "best fit" and when using a larger size on the same size head, the eye clearance measurements increased. Since the foam thickness and the distance from the foam to the ANVIS mount are approximately the same for the different sized helmets, the measured differences in eye clearance with helmet size has to be a function of both the compression of the TPL and a greater distance from the forehead to the eyes with proportionally larger head sizes. However, as the helmet sizes increased using the "best fit" criteria, the average ANVIS vertical height position did not increase. This is because the helmets were fitted to provide approximately 1-1/2 inch distance between the physical eye height and the base of the helmet foam liner.

The subjects were not allowed to adjust the tilt lever, which would affect the ANVIS vertical height position when the user is aligned optically. The large range of relative helmet tilt angles measured when the subjects thought their heads were in a natural level position would indicate that subjects are not very sensitive to small head tilt angles, the perceived head level position varies considerably between subjects, and/or the

helmet tilt angle varies when the helmet is properly fitted on different subjects. The preferred ANVIS tilt lever position would be an individual as well as a possible type aircraft variable.

The protective mask fitting and compatibility data are insufficient for any meaningful statistical analysis, but the general trend and impressions of the investigators are that a larger sized helmet than the Gentex recommended size for a given subject will be required to provide an acceptable helmet/mask compatible fit and adequate comfort for the M-43 or any other type mask. The subjects only wore the helmet and mask for a few minutes, and less than 80% had either an acceptable fit or tolerable comfort with this combination. If the mask is not compatible with the helmet, then compatibility with night vision devices is meaningless.

The number of unacceptable ANVIS compatible alignment with the helmet and mask for the small sample were only considered for insufficient vertical adjustment range. A larger percent of the helmet/mask/ANVIS wearers would be expected to have excessive eye clearance with reduced fields of view through the ANVIS.

Method 2- Eye clearance and tilt angles measured using HGU-56/P helmets and rigid head forms

Procedure

In the second phase of the experiment, five rigid model heads of different sizes and types were fitted with the following HGU-56/P helmets: (1) the recommended helmet size IAW Gentex fitting method, (2) the next size smaller, and (3) the next size larger than the recommended size. The headforms represented the small, medium, and larger Army aviator, an extra large Air Force aviator, and a very small commercial mannequin. The researcher that measured the head sizes of the flight personnel in the first helmet fitting procedure also measured the head dimensions of the rigid headforms. Measurements were made of the head length, breadth, and circumference. Head breadth is a measurement from above the ears across the top of the head. The dimensions of the USAARL aviator rigid headforms are based on triservice anthropometric data (USAARL, 1988).

The ANVIS tilt lever was placed in the middle position; the ANVIS fore-aft was adjusted to the most rearward position; and the eyepiece diopter value set at -0.50 diopters. The ANVIS interpupillary distance (IPD) setting was estimated by the vision researcher to match the headform. Note that the ANVIS IPD setting would not affect eye clearance measured with the optical method used in this study.

The researcher then attached ANVIS to the helmet and set the vertical adjustment height measured from the top to the following values: 3, 7, 11, and 15 mm (available range 0 to 17 mm). The helmet then was tilted until the eye position appeared to be aligned with the center of the ANVIS eyepieces. The headform and helmet were tilted together until the tilt of the ANVIS tubes were horizontal.

Measurements of the eye clearance for right and left eyes were taken with the modified telescope (or parallax ruler if necessary) and a distometer, which is a caliper. There are several differences in the measured values between the mechanical and optical methods. The telescope and parallax ruler measure <u>eye clearances</u> between the apex of the cornea and the last visible structure in front of the eye (ANVIS eyepiece housing in this case). The distometer measures the <u>vertex distance</u> between the apex of the cornea through a closed eyelid and the center of last optical element in the ANVIS eyepiece. The last optical element in the ANVIS eyepiece is recessed approximately 2 millimeters in the optical housing. The distometer reading assumes a eyelid thickness of 1 millimeter.

The helmet tilt angle and ANVIS tilt angle were measured from the leveled head position by placing the inclinometer on top of the helmet and visor cover for one measurement, and along the bottom of the ANVIS imaging tubes for the second measurement. The algebraic difference between the two angles would be the correction factor to be used to determine the ANVIS tilt angle in degrees from a horizontal plane for the subjects used in the HGU-56/P helmet fitting study. The bases of the aviator headforms were fabricated to position the head in a perceived "level position" when placed on a level surface.

Results

Head size was based on head length as recommended by the Gentex fitting guide for selection of the recommended size HGU-56/P helmet. The Gentex recommended helmet size for head length is reproduced using millimeters and inches in Table 4 for reference, and the measurements of the headforms and manufacturer's recommended helmet sizes are listed in Table 5.

Table 4.
Gentex recommended helmet size for head length.

Head length millimeters/inches	Recommended helmet size
<181 mm/ 7.11"	-2
181 - 188 mm/ 7.11-7.4"	0
188 - 196 mm/ 7.41-7.7"	2
196 - 203 mm/ 7.71-8.0"	4
203 - 211 mm/ 8.01-8.3"	6
>211 mm/ 8.31"	8

Table 5.
Rigid headform measurements in millimeters.

Head Size*	Circumference	Width	Length	% to RHS**
-2	521	145	173	<01%
2	578	156	196	99%
4	572	156	201	71%
6	597	163	210	88%
8	640	175	223	>99%

* Head Size is based on Gentex fitting guide from head lengths referenced in Table 4.

** Percent to RHS is the head size percentile length to the recommended helmet size. Example: If the head length of the rigid headforms were midway between the range for a given recommended helmet size, then the percent to RHS would be 50 percent; with a head length of 210 mm to be fitted in helmet size 6 (203 mm to 211 mm), the RHS is 7/8 or 88 percent.

Minimum ANVIS eye clearance measurements

For a given headform and helmet size, the minimum ANVIS-eye clearance distance was measured for every vertical ANVIS position and each eye using both the telescope (TEL) or ruler and the distometer (DIS). Averages and standard deviations (SD) were calculated from these measurements and are shown in Table 6.

Table 6.
Minimum eye clearances measured with telescope (TEL); minimum vertex distance measured with distometer (DIS).

Head size	Helmet size	TEL/(SD)	DIS/(SD)
-2	-2	19.2mm (1.5)	22.3mm (1.2)
-2	0	Helmet too large for head	
2	0	10.1mm (0.8)	10.8mm (1.2)
2	2	14.6mm (2.4)	16.4mm (2.4)
2	4	17.3mm (1.7)	19.5mm (2.1)
4	2	9.4mm (1.7)	10.5mm (1.3)
4	4	12.8mm (1.0)	14.5mm (1.6)
4	6	14.5mm (1.7)	16.6mm (1.2)
6	4	7.4mm (1.5)	9.3mm (1.5)
6	6	11.2mm (2.0)	Not Taken
6	8	17.2mm (1.2)	Not Taken
8+	We could not get any size HGU-56/P helmet on the Air Force extra large headform		

A plot (Figure 12) of the eye clearance averages for each headform that was fitted with the recommended, one size smaller, and one size larger helmet shows that increasing the size of the helmet on a given head size to the next helmet size will increase the eye clearance by approximately 3.7 millimeters. Note that the helmet sizes are in increments of 2.

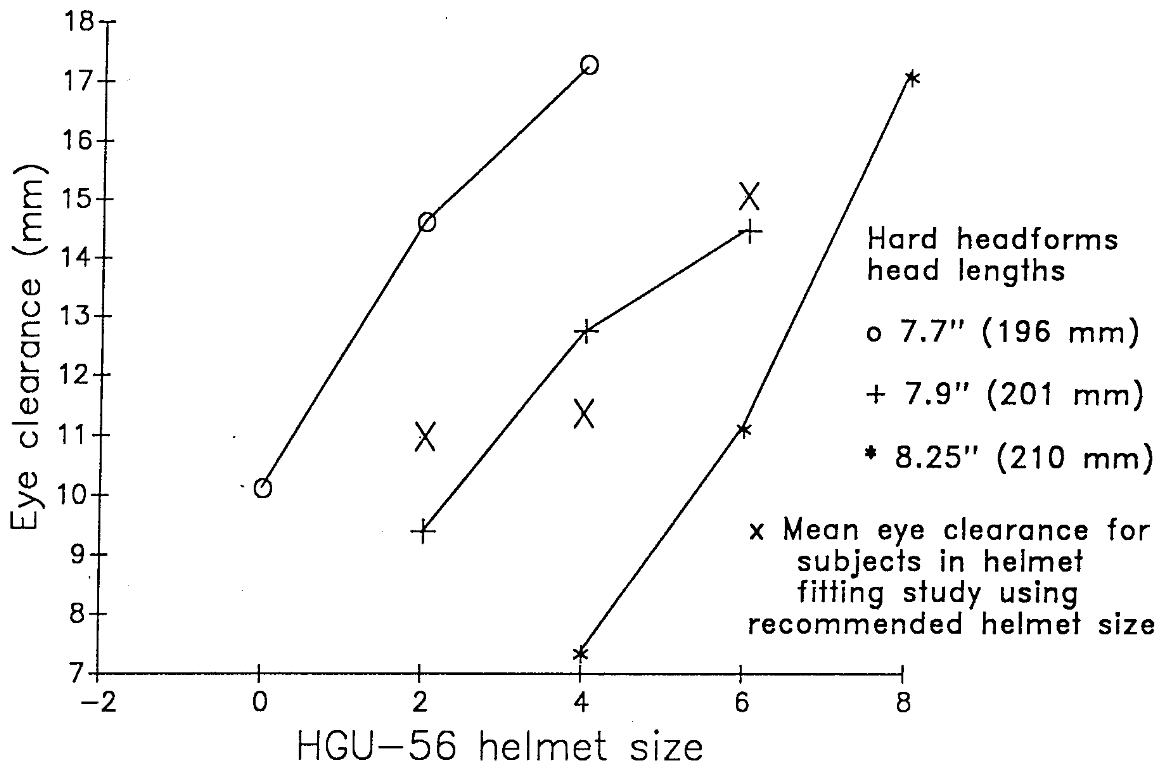

Figure 12. ANVIS minimum eye clearance on three different size HGU-56/P helmets and rigid headforms.

Distometer vs telescope
vertex distance and eye clearance

The average difference between the measurements with the telescope and the distometer for a given condition was 1.8 millimeters, with a range of 0.7 to 3.1 millimeters. The distometer readings were higher than the optically measured eye clearance. The correlation coefficient between the readings of eye clearance with the telescope and the vertex distance measured with the distometer was 0.995. The regression equation for best fit between the data is y = 1.1x + 0.06; where y is the distometer value and x is the eye clearance value measured with the telescope. See Figure 13.

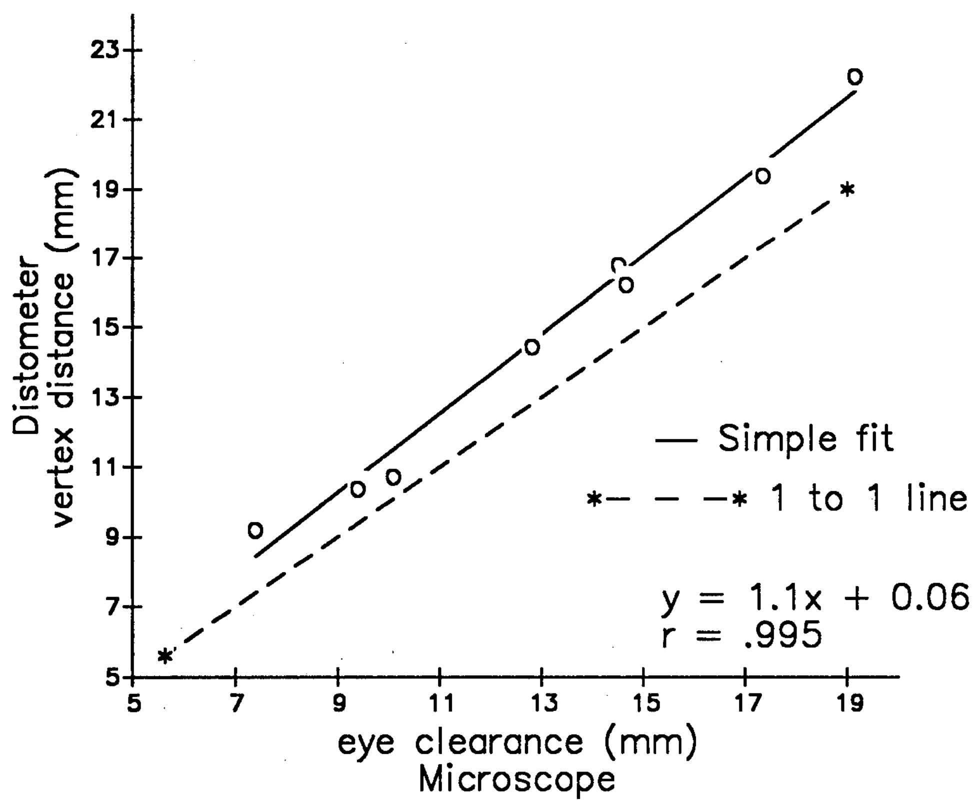

Figure 13. Comparison of vertex and eye clearance distances, ANVIS and HGU-56/P helmets on rigid headforms.

Right eye vs left eye clearance measurements

For the four measurable headforms, the average difference in measured eye clearance between the left and right eyes, using the telescope was -0.94 mm (right eye had slightly greater eye clearance than left).

Tilt measurements

If the vertical adjustment height is changed on the ANVIS mount without changing the position of the ANVIS tilt lever, then the helmet would be required to be rotated about the pitch axis to realign the apparent visual and the ANVIS eyepiece optical axes. A change of 12 mm in the vertical adjustment range for ANVIS with the HGU-56/P helmet, sizes 0 to 8, resulted in an average helmet and goggle tilt change of 6.5 degrees.

The average difference between the measured relative helmet tilt angle and the ANVIS tilt angle was 7.6 degrees (1.9 degrees standard deviation) using data from helmet sizes 2, 4, 6, and 8. Therefore, a relative downward tilt angle measurement of 7.6 degrees with the inclinometer resting on the top of the helmet and visor cover would result in the ANVIS tubes being horizontally level.

Discussion

Increasing the helmet size on the same size headform, showed an increase in measured ANVIS eye clearances. This eye clearance increase would be primarily from less compression of the TPL with the larger helmet size since the foam liners, helmet shells, visor covers, and ANVIS mounts have the same thickness for all helmet sizes.

The apparent excessive eye clearance measured with helmet size -2 and the small mannequin headform can be explained by the two extra dimple layers in the TPL normally used in the -2 helmet size and the extremely small head size. The dimensions of the -2 size helmet are identical to the 0 size helmet. However, the -2 helmet size has 2 extra dimple layers in the TPL.

The difference between the eye clearance measured with the telescope and the distometer averaged approximately 1.8 millimeters, with the distometer indicating a higher value. This difference between the measuring devices can be explained by both the reference points and a 1 millimeter factor that is included in the distometer reading to compensate for the thickness of the eyelids on a human subject. The distometer measures between the center of the last lens element in the eyepiece and the eyeball over a closed lid. Of course, the rigid headforms did not have

closed eye lids. The last lens element usually is recessed 1 to 2 millimeters inside the lens mount of the ANVIS eyepiece.

The 1-millimeter average difference found between the eye clearance measurements of the right and left eyes of the rigid head forms would not be considered significant with the range of measured differences between -4 and +3 millimeters. This small difference could be attributed to a number of factors such as slight differences in the headforms, the centering of the ANVIS mounts, or just experimental error with measurements taken in 1 millimeter increments.

The relative helmet tilt angles were measured with the hard headforms only to determine an approximate ANVIS tilt angle from the relative helmet tilt angles that were measured during the helmet fit portion of the study. The vertical adjustment for the ANVIS was varied throughout the available range, and the helmet was tilted by the investigator to alignment in front of the apparent eyes of the hard headform, without regard to the recommended 1-1/2 inch distance from the eye to the foam liner of the helmet.

Conclusions

Using a large aviation population sample showed that a very high percentage of the intended users of the HGU-56/P helmet will have acceptable ANVIS compatibility without any TPL custom fitting for both eye clearance and vertical adjustment position. The data also suggest that moving the ANVIS mount upward on the helmet should increase the percentage of pilots with acceptable ANVIS compatibility.

Compatibility of the M-43 protective mask with the HGU-56/P helmet and ANVIS was not adequately assessed in this study, but the subjective responses and the investigators' opinions strongly suggest that there may be a potentially unacceptable high percentage of mask/helmet users that can not obtain either an acceptable helmet fit or ANVIS compatibility. If the typical military criteria of fitting the 5 to 95 percentile and achieving ANVIS compatibility is required for the mask/helmet/ANVIS combination, then these limited data and observations are sufficient to show that the HGU-56/P helmet when worn with the M-43 mask would fail this criterion. This needs to be resolved.

Rigid headforms are an excellent means to evaluate the relative differences between helmet types for compatibility with night vision devices such as the ANVIS. However, each headform will have its own unique calibration factors for different types of head dimensions if used to represent different populations. This study includes ANVIS eye clearance data on both an aviation population and different sized rigid headforms.

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Appendix A.

Experimental data in tabular form.

Table A.
The number and percent of unacceptable ANVIS compatibility with HGU-56/P Helmet by helmet size. Unacceptable (UN) is defined as excessive eye clearance (EC) or insufficient vertical (Vert) range adjustment.

Size helmet	1 helmet size down- same size head	Gentex recommended helmet size	1 helmet size up- same size head	Totals
-2	EC=0 Vert=0 N=7 0% UN	EC=0 Vert=0 N=2 0% UN	Not applicable	EC=0 Vert=0 N=9 0% UN
0	EC=0 Vert=1 N=10 10% UN	EC=0 Vert=0 N=13 0% UN	EC=0 Vert=0 N=2 0% UN	EC=0 Vert=1 N=25 4% UN
2	EC=0 Vert=1 N=18 6% UN	EC=0 Vert=5 N=41 12% UN	EC=0 Vert=2 N=14 14% UN	EC=0 Vert=8 N=73 11% UN
4	EC=0 Vert=0 N=12 0% UN	EC=1 Vert=3 N=55 7% UN	EC=1 Vert=9 N=45 22% UN	EC=2 Vert=12 N=112 13% UN
6	EC=0 Vert=0 N=4 0% UN	EC=4 Vert=0 N=25 16% UN	EC=5 Vert=5 N=50 25% UN	EC=9 Vert=5 N=79 17% UN
8	Not applicable	EC=0 Vert=0 N=6 0% UN	EC=4 Vert=4 N=29 28% UN	EC=4 Vert=4 N=35 23% UN

Notes for Tables B through G: The data include the unacceptable ANVIS compatibility from either insufficient vertical adjustment range or excessive eye clearance distances. For the mean calculations, the unacceptable vertical values are assigned a value of 0 millimeters. If the vertical height was unacceptable, the fore-aft was not measured or included in the calculations.

* Note for Tables B, C, and D: The vertical height adjustment value is always greater for helmet size 0 than for the other sizes. The reason is not known. Measurements of the helmet shell, foam, and TPL thicknesses were the approximately the same as the other sized helmets.

Table B.
Vertical adjustment-Gentex recommended.

Helmets included	N	Mean	SD	5%	50%	95%
Size -2	2	7.5	NA	NA	NA	NA
Size 0*	13	8.9	4.2	0.7	9.5	13.4
Size 2	41	5.0	4.4	0.0	4.1	11.5
Size 4	55	5.4	3.8	0.0	4.3	11.2
Size 6	25	5.8	4.2	0.0	4.5	11.0
Size 8	6	6.3	3.1	4.0	4.5	11.1

Table C.
Vertical adjustment - one size smaller.

Helmets included	N	Mean	SD	5%	50%	95%
Size -2	7	7.6	2.9	3.0	6.8	12.0
Size 0*	10	9.8	5.6	0.0	11.0	15.5
Size 2	18	7.2	3.0	3.0	6.5	11.0
Size 4	12	6.9	2.8	3.0	6.3	11.4
Size 6	4	9.3	2.6	NA	7.0	NA
Size 8	NA	NA	NA	NA	NA	NA

* Note for Tables B, C, and D: The vertical height adjustment value is always greater for helmet size 0 than for the other sizes. The reason is not known. Measurements of the helmet shell, foam, and TPL thicknesses were the approximately the same as the other sized helmets.

Table D.
Vertical adjustment - one size larger.

Helmets Included	N	Mean	SD	5%	50%	95%
Size -2	NA					
Size 0*	2	10.5	.7	NA	NA	NA
Size 2	14	3.7	3.5	0.0	3.0	8.5
Size 4	45	4.1	3.8	0.0	2.7	11.0
Size 6	50	4.4	3.0	0.0	3.6	9.3
Size 8	29	3.4	3.1	0.0	2.6	8.1

Table E.
Minimum eye clearance - Gentex recommended.

Helmets included	N	Mean	SD	5%	50%	95%
Size -2	2	9.5	NA	NA	NA	NA
Size 0	13	9.1	4.0	3.0	7.8	15.4
Size 2	36	10.8	4.3	2.8	10.5	17.3
Size 4	52	11.4	3.8	3.6	10.9	16.8
Size 6	25	16.1	4.1	10.0	16.3	20.9
Size 8	6	15.7	2.7	12.0	14.0	19.1

* Note for Tables B, C, and D: The vertical height adjustment value is always greater for helmet size 0 than for the other sizes. The reason is not known. Measurements of the helmet shell, foam, and TPL thicknesses were the approximately the same as the other sized helmets.

Table F.
Minimum eye clearance - one size smaller.

Helmets Included	N	Mean	SD	5%	50%	95%
Size -2	7	6.6	5.5	-2.0	5.8	13.3
Size 0	9	9.8	3.7	4.0	9.3	14.6
Size 2	17	9.4	2.3	6.0	8.8	12.6
Size 4	12	11.7	5.0	5.0	10.0	18.4
Size 6	4	13.3	3.9	NA	13.0	NA
Size 8	NA	NA	NA	NA	NA	NA

Table G.
Minimum eye clearance - one size larger.

Helmets Included	N	Mean	SD	5%	50%	95%
Size -2	NA	NA	NA	NA	NA	NA
Size 0	2	15.5	NA	NA	NA	NA
Size 2	12	11.0	3.7	3.0	10.3	15.2
Size 4	36	13.6	4.1	3.6	13.3	19.1
Size 6	45	16.7	3.4	11.1	16.1	21.8
Size 8	25	17.3	3.1	11.0	17.0	21.7

Appendix B.

M-43E1 mask field-of-view with ANVIS, with and without prototype frontsert optical correction.**

by
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(Unpublished Data)

1. Eye clearance measurements (in millimeters) by mask size. Measurements taken with slit lamp and electronic digital fore-aft position indicator:

a. From the cornea to the back surface of the mask lens along the line of sight in millimeters:

	Small	Medium	Large	X-large	Combined
N	2	5	6	2	15
Average	7.2	12.2	7.5	6.6	8.9
Range	5.6-8.7	7.5-15.0	5.4-9.4	5.2-8.0	5.2-15.0

Standard deviation = 3.2

b. From the cornea to the front surface of the type II frontsert:

	Small	Medium	Large	X-large	Combined
Average	19.8	22.6	19.4	18.2	20.4
Range	18.8-20.8	21.0-24.2	17.4-22.4	14.6-21.9	14.6-24.2

Standard deviation = 2.6

Note: Six of the 15 subjects needed eye cushions to achieve the mask fit. One of the subjects with the medium sized mask used two sets of cushions.

** Since this evaluation, the frontserts and nose staples were changed. During the M-43 frontsert study, ANVIS eye clearances were measured using the rigid headforms and will be reported in a future USAARL report.

2. ANVIS field-of-view (FOV):

a. Using the same 15 subjects that were used for the vertex distance measurements, the horizontal FOV in degrees was measured using ANVIS, M-43, type 2 protective mask with and without frontsert corrective lenses. It was not stated whether the FOVs were binocular or monocular. The following table shows the conditions evaluated:

Condition	Equipment configuration
No mask	Helmet + ANVIS
Mask	Helmet + M-43 mask + ANVIS
Frontsert	Helmet + M-43 mask + frontsert + ANVIS

The ANVIS IPD was adjusted to the user's IPD. However, the nose staples that were used were much smaller than indicated by the IPD. The average staple size used was 55 millimeters, ± 2 mm S.D. and the average subject IPD was 63 mm, ± 2.5 mm S.D. The narrower IPD staples would allow the ANVIS eyepieces to be moved closer to the mask lenses.

b. The mean, standard deviation, and range for the differing conditions is as follows:

Condition	Mean	Standard deviation	Range
No Mask	38.5	1.2	35.9-39.7
Mask	37.8	1.2	35.0-39.2
Frontsert	37.3	1.6	33.6-39.8

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NASA Lewis Research Center
Cleveland, OH 44135

U.S. Air Force Institute
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Building 640, Area B
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Air Force Base, OH 45433

Commanding Officer
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AAMRL/HEX
Wright-Patterson
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Assistant Commandant
U.S. Army Field Artillery School
ATTN: Morris Swott Technical Library
Fort Sill, OK 73503-0312

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Man-Machine Integration System
Code 602
Naval Air Development Center
Warminster, PA 18974

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ATTN: Code 602-B
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Naval Air Development Center
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Technical Support Detachment
Warminster, PA 18974

Strughold Aeromedical Library
Document Service Section
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Brooks Air Force Base, TX 78235-5122

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U.S. Army Health Services Command
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Fort Sam Houston, TX 78234-6000

U.S. Army Medical Department
and School
USAMRDALC Liaison
ATTN: HSMC-FR
Fort Sam Houston, TX 78234

Commander
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Fort Sam Houston, TX 78234

U.S. Army Dugway Proving Ground
Technical Library, Building 5330
Dugway, UT 84022

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